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THE USES OF BITUMEN IN HYDRAULIC ENGINEERING

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THE USES OF BITUMEN IN HYDRAULIC ENGINEERING

by

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INTRODUCTION

(1) The development of modern methods of refining crude oils has opened up many diverse fields for the use of the large quantities of bitumen now produced and available the world over. One of these fields is that of hydraulic engineering, where the versatile product bitumen is now being used, as such or in asphalt compositions, as a building material of specific technical value and of relatively low cost in all climates, both above water to high altitudes and under water to considerable depths.

(2) The object of this paper is to give a short review of a choice of applications of bitumen in hydraulic engineering that may be of benefit to less developed areas if used to suit local circumstances.

IRRIGATION CANALS

(3) Aiding the advance of agriculture in many areas of the world are modern systems of irrigation. An essential feature of a successful scheme is to reduce seepage losses of valuable water to a minimum when on its way through canals from source to field. This purpose can be achieved in various ways with bitumen in diverse forms of application.

(4) In existing earth canals or in old, concrete-lined canals, seepage losses of water can be reduced to a minimum by temporarily closing the canal in sections to reduce the velocity of the canal water and then applying a slow-breaking bitumen emulsion which will gradually close the pores in the soil as the canal water percolates through the earth or concrete-lined perimeter of the canal.

(5) Again in existing canals the same purpose can be achieved by lining a canal in service with overlapped prefabricated reinforced asphalt mats or rolls, laid under water.

(6) The former principle of using prefabricated, reinforced mats is suitable also for waterproofing canals in the dry, in which case the mats are generally jointed with an asphalt compound. This method is particularly suitable for small jobs where access to the canal through fields is difficult.

(7) A low cost method of rendering a dry canal waterproof has been devised by the U.S. Bureau of Reclamation, Denver, Colorado, and is used extensively in the arid parts of the U.S.A. It consists of overexcavation of a canal, trimming the perimeter and spraying hot blown bitumen to a thickness of 6 mm. This bitumen membrane is then buried under a layer of the overexcavated material at least 30 cm. thick to protect it against possible mechanical damage or being destroyed by hooves of animals.

(8) A bitumen membrane has also been successfully used in Pakistan as a waterproofing medium to a thickness of 3 mm. in the age-old method of canal lining interposed between two layers of brick tiles measuring 30 x 15 x 5 cm.

(9) For canals where the surface to be covered is of sufficient importance to bear the cost of installing a hot-mix asphalt installation as used for road work, the application of an asphaltic concrete or a sand asphalt lining is the most effective construction. This is a surface lining laid to a thickness of at least 4 cm. The hot-mix asphalt material is laid by hand or mechanically and then completed by rolling. It renders not only the canal perimeter impermeable but has some additional advantages. Firstly, from a hydraulic point of view, one advantage is that an asphaltic concrete lining is smooth, the coefficient of roughness of the surface being 0.015 for Manning's Formula, and another is that it can be laid in a parabolic form to obtain maximum flow capacity of the canal for a minimum cross-section. This type of lining is continuous as it is laid without joints, it is sufficiently plastic and flexible to follow natural settlements of well-designed and compacted stabilized soil fills without losing its properties of resistance to creep on a slope and of strength to withstand movement of heavy animals, if applied to the required thickness. Since asphaltic concrete is a visco-elastic type of material it is clear that drainage should be provided for where hydrostatic uplift and undue deformation of the lining might otherwise occur and than an effective soil sterilization should take place (such as a 5% solution of sodium chlorate in water sprayed at a rate of 2 litres/m^2) to prevent weed-growth through the lining. A final, but not less important, advantage is that hot-mix asphalt linings can be laid at competitive cost as compared with other materials. These asphalt linings have been in service for more than 20 years without requiring practically any maintenance.

(10) A number of sand asphalt canal linings have been laid in Egypt with very satisfactory results for large extensions of irrigation areas in the lower Nile valley.

LARGE DAMS AND RESERVOIRS

(11) The energy resources of an area must generally be developed in order to tap a country's full potential, and hydro-electric power as a basis for industrial expansion can contribute to the national wealth in many instances. Dams and reservoirs must be built for the conservation of water needed for the exploitation of hydro-electric schemes and hot-mix asphalt materials play their part as impermeable courses or structures in retaining the water in the required quantities for use at times specified for a correct functioning of the delivery of electricity.

(12) The standard example of the construction of an impermeable asphaltic concrete layer on the upstream surface of a rock-fill dam is that of the Ghrib Dam in Algeria. The 25th anniversary of the historical event of the first filling with water of the great valley closed by the dam should not be allowed to pass without mentioning the name of Mr. G. Drouhin, former President of the International Commission on Irrigation and Drainage, to whose initiative during the preliminary design period and later on during construction the complete success of this first important asphalt dam construction is mainly due. A performance of a total water seepage of a pail of water per minute for a dam of 62 m. maximum height at very low annual maintenance costs can hardly be surpassed. The initial cost of the two-course asphaltic concrete layer of 12 cm. total thickness was also much lower than estimates for other materials showed.

(13) On rock-fill and earth-fill dams built in later years the upstream face is generally not so steep, the usual practice being to form a slope of 1:1.75 maximum and preferably 1:2. Separation of control drainage pipes for possible seepage water through the asphalt surface, under the dam and round the abutments is always advisable for more rapid location and assessment of seepage which normally would have to be followed by repair work.

(14) Although the construction of an impervious facing to a dam has the advantage of being easy to lay and to repair, if necessary, and can serve simultaneously as a protective layer it is, of course, more vulnerable to damage and destruction than an impervious core. The principal advantage of an impervious facing is, however, a matter of dam stability in that the whole body of the dam remains permanently dry, whereas the upstream side of the impervious core of a dam is generally saturated, resulting in a lower density of the component materials and consequently a lower resistance to shear. A third possibility of placing the impervious structure is in an intermediate position as a sloping construction. The latter is built up at the same time as the dam proper, to a width of at least 1.20 m. for constructional reasons, by vibrating boulders of similar size as used for the dam proper into consecutive layers of rich asphaltic concrete by means of special vibrating devices. In this way an impervious screen is formed by a skeleton of boulders between which the voids are filled with the asphalt material thus forming a mass of a stability at least equal to that of the dam itself.

(15) It is an acknowledged fact that earth and rock-fill dams are normally built where the bearing capacity of the soil is low but the cost of earth movement by modern large capacity equipment is decreasing to such an extent that their construction may be preferable also in other conditions. These two types of dam fit more naturally in the configuration of surrounding soil than slender concrete dams, their width at the bottom and abutments ensure greater resistance to movement and piping and they can even contain an impervious asphalt facing as well as a semi-pervious asphalt core of boulders and open-graded asphalt material such as bituminous macadam. The object of the latter is to have a braking effect on the rush of water through a rock-fill dam in case it is severely damaged on the upstream side. The consequences of an unexpected failure in the dam or its junctions to the adjacent soil should always be seriously considered and the possibility of reducing the energy of the rushing water following a sudden local break in a dam by means of a semi-porous central asphalt screen may be of great value where a dense population or a valuable agricultural or industrial area would otherwise be endangered.

(16) This type of construction would seem particularly of value in countries where earthquakes occur.

(17) As regards reservoirs built in soil for hydro-electric purposes, many of which are located in less favourable surroundings than those built in earlier years, particularly those of the compensating reservoir type, need durable solid linings. It is becoming evident that the established method of lining is with asphaltic concrete applied in a two-course layer with staggered joints to a mimimum compacted total thickness of 7 cm. on a levelling course or drainage course of bituminous macadam. For further technical considerations and details of construction, reference can be made to previous paragraphs.

RIVER BANKS

(18) Although river training works are not frequent in less developed areas and are limited to certain sections of water courses, concave river bends may need strengthening of river banks to protect adjacent cultivated land, industrial or residential areas and engineering structures such as roads, railways and abutments of bridges against erosion and floods. A strong and durable asphalt bank protection requiring little or no maintenance is the asphalt-grouted rubble or stone revetment. It consists of hand pitching grouted or penetrated with a sand mastic, that is a rich sand asphalt applied hot by gravity flow from a bucket or container through a steel chute. The thickness of the revetment depends on local conditions but may vary from 30 cm. to 1.00 m. for torrential streams carrying large boulders. A strength test was carried out on the River Arc in France recently to demonstrate that an asphalt grouted hand-pitching of 50-60 cm. thickness would resist the impact of boulders weighing from 800 to 1,600 kg. falling from a height of about 12 m. without showing more than a scarred facing.

NAVIGATION CANALS

(19) In European countries many long-service asphalt canal linings and bank revetments exist but this type of construction is only exceptionally needed in less developed areas. The type of structure used for this purpose is either an asphaltic concrete revetment or an asphalt grouted hand pitching as described in the previous paragraphs.

HARBOUR MOLES AND DAMS

(20) The first harbour dam was built 15 years ago in the Netherlands consisting of a sand core built according to the hydraulic fill process by pumping water and sand through a pipe, the sand being deposited in very compact formation at the end of the pipe and the water draining off gradually. The protection of the dam consisted of a sand asphalt layer provided with a seal coat of bitumen covered with sand. Only little maintenance work has been carried out from time to time. The established method of protecting dams of this type for the immense 25-year Delta Plan scheme consists at present of constructing an asphalt grouted hand-pitching under mean high water spring tide and above that level a dense asphaltic concrete revetment.

(21) A breakwater of a completely different type was strengthened many years ago by asphalt grouting the protection, consisting of 15-ton concrete blocks, of a vertical concrete wall. Rubble was dumped in the hot sand mastic as it flowed by gravity through a steel chute into the interstices between the large concrete blocks.

(22) Rubble mound breakwaters can be duly strengthened against storms by providing an asphalt grouted facing or cap covering the seaward side, crest and harbour side. The structure is not only made more resistant to breaking waves but turbulence is reduced by forming a streamlined construction. This is the basic principle of the success of this type of structure. The asphalt grouting material can be accurately placed above as well as under water level.

COASTPPROTECTION

(23) Sea walls protected by asphaltic concrete revetments or asphalt grouted hand pitching are now being built according to well-established methods of construction based on many years of experience. The methods of applying these asphalt constructions have been described in previous paragraphs. A fiThe illustration shows a typical example of one of the long sea walls built in Japan after heavy destruction was caused by typhoons in September, 1959. It shows the importance of providing protection to the rear side of the sea walls to prevent damage by waves washing over the crest which are always the initial cause of a breach, followed by complete destruction of the sea wall and flood disaster.

(24) Many years of experience combined with continuing research work in laboratories and field investigations on the characteristics and performance of asphalt constructions related to hydraulic problems such as wave attack, hydrostatic uplift and percolation of water are forming the scientific basis to ensure the success of the use of bitumen and its compositions for hydraulic constructions.

(25) The author is indebted to this United Nations Conference to have been invited to present this paper and trusts it will be to the benefit of the less developed areas.

Figure 1 - JAPAN : Nabeta Polder - Asphalt protection of rear side of seawall to prevent breaching

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